WASTE MANAGEMENT AND DISPOSAL STRATEGIES IN IAEA MEMBER STATES WITH NUCLEAR POWER PROGRAMS

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ABSTRACT

As of the end of 1991, 28 IAEA Member States had electricity generating nuclear power reactors in operation or under construction. There are currently 420 operating units worldwide, with a total capacity of about 326 gigawatt-electric (GWe). In addition, there are 76 units under construction, which would bring the total electrical generation capacity to about 390 GWe.

Generating electrical power, whether the energy source is coal, oil or nuclear, results in a by-product. In the case of nuclear power, the by-product of concern is radioactive waste.

The management of radioactive waste is not a new concept. It has been practiced for low and intermediate level wastes (LLW/ILW) for more than 35 years. For high level waste (HLW), including spent nuclear fuel, many countries with nuclear power are developing strategies, approaches and technologies for its disposal.

Disposal facilities for low and intermediate level waste and other short lived wastes are in operation. Currently, there are three common disposal options used for these types of waste; direct land disposal, near surface facilities, and geologic repositories.

There is agreement that interim storage will be an important component of the waste management system - as most countries plan to store spent fuel and/or vitrified HLW for at least 20-50 years prior to disposal. Presently, spent fuel is stored at-reactor or at away-from-reactor storage facilities. The spent fuel will either be conditioned prior to disposal (for "direct disposal") or be reprocessed. For the latter option, the resulting HLW would be immobilized into a glass form and placed in interim storage until, as with spent fuel, a disposal facility (e.g. a geologic repository) is available. To date, about half the countries with nuclear power are planning direct disposal of conditioned spent fuel.

INTRODUCTION

The use of the atom has come a long way since that famous day in December 1942 in Enrico Fermi's lab. Since then, the atom has been applied to many uses, including the eradication of worms and files, shelf life extension of fruits and vegetables, medical research and therapeutic applications, and most notably, generation of electricity. Nuclear power in 1991 supplied over 23% of the total electricity in countries of the OECD (Organization for Economic Co-operation and Development) and about 17% worldwide.

However, using the atom creates a by-product of concern: radioactive waste. Although all activities generate some waste, most comes from nuclear fuel cycle activities that support nuclear power plant operations. These activities include four main categories, which are uranium or thorium mining and milling; fuel conversion, enrichment and fabrication; nuclear power plant operations; and decontamination and decommissioning. The types of waste generated are diverse in terms of levels of radioactivity, physical characteristics and volumes.

QUANTITIES OF RADIOACTIVE WASTE

As mentioned earlier, the majority of the radioactive waste arises from the generation of nuclear power. Thus, if nuclear energy is to achieve its potential, countries with or planning nuclear power must develop effective waste management programs that will safely isolate radioactive wastes from man and the environment.

While the actual volumes of waste generated from nuclear energy are small relative to other energy industries and alternatives such as coal burning power stations, one of the major concerns of nuclear energy is the long period of time that radioactive wastes can pose radiological risks to man and the environment. Although the larger portion of the radioactive waste generated has a relatively short half-life (20 to 30 years) there are some elements of the waste product that have half-lives of hundreds to thousands of years.

DISPOSAL STRATEGIES FOR LOW AND INTERMEDIATE LEVEL WASTE

The management and disposal of low and intermediate level waste (LLW/ILW) in Member States with nuclear power plants have been established and proven during the past 35 years. In the early days, LLW/ILW was usually disposed of in near surface disposal facilities, sometimes referred to as shallow ground burial sites, with little or no treatment and conditioning. However, as national programs developed a better understanding of the effects and impact of waste disposal, many countries redefined their disposal strategies and practices.

In most Member States, the disposal strategy for LLW/ILW includes near-surface disposal facilities and geologic repositories. In some countries, the present strategy is to dispose of these wastes in deep rock formations. The four major options currently used or planned by countries for waste disposal are 1. near surface disposal facilities, 2. rock cavities, 3. sea coastal facilities, and 4.) geologic repositories.

Status of Low and Intermediate Level Disposal Programs

Recently, significant progress in this area in a number of Member States has been achieved. Four LLW/ILW disposal facilities began operations in Finland, France, Japan and Spain in 1992.

In early 1992, the Finnish utility Teollisuuden Voima Oy (TVO) completed construction of a final LLW/ILW repository at Olkiluoto, the location of the first nuclear power plant (NPP) site in Finland. The facility is an excavated cave in the bedrock to a depth of about 70 meters. Waste from TVO's Olkiluoto Nuclear Power Plants will be stored in 200 liter drums in two rock silos. The repository's total capacity is approximately 13,000 drums. A decision on the need for additional LLW storage capacity at the Lovissa NPP site is expected in 1994. At present, it appears that existing storage facilities are large enough for the life of the plant.

A disposal facility Centre de l'Aube near Soulaines, France, located approximately 200 kilometers southeast of Paris, received its first shipment of waste in January 1992. The Centre de l'Aube will replace the Centre de La Manche which has been in operation since 1969. The La Manche disposal facility will continue to operate until 1994; however, permanent closure of the facility is not planned for a number of years. The waste volume at the La Manche facility is about 500,000 cubic meters of short lived waste. Centre de l'Aube will have a disposal capacity of at least 1.2 million cubic meters of packaged short lived LLW/ILW.

Japan Nuclear Fuel Limited (JNFL) was authorized in late 1992 to begin operation of its disposal facility for low level waste from the country's nuclear power plants. The disposal facility is located in Rokkasho in Aomori Prefecture. Construction of a repository for 50,000 drums (200 liters each) was completed in November 1992. The facility is to be enlarged gradually to hold up to one million drums of waste - with an ultimate target of three million drums.

Spain's final storage/disposal facility for LLW/ILW at El Cabril in the Andalucia Region began operating in 1992. Spain's disposal model is very similar to that being used by the French - a near surface disposal concept with engineered barriers. During the first phase, El Cabril has a capacity for about 60,000 cubic meters of waste which is expected to be sufficient until the year 2000. ENRESA is the organization in Spain responsible for all aspects of radioactive waste management.

Meanwhile, site selection and investigation studies to locate LLW/ILW disposal facilities continue in several countries. Some programs are just beginning while others are nearing the construction and operation phase.

The LLW generated by Belgium's seven nuclear power plants is treated and stored on-site for short periods of time. Solid LLW/ILW will be placed in an interim storage facility at Mol until the repository is available in the mid-1990s.

The LLW generated by the 18 nuclear power plants in Canada, is temporarily stored on-site. A surface land disposal facility is in operation at Chalk River, Ontario, and is used by Atomic Energy of Canada, Limited (AECL) and Ontario Hydro for LLW disposal. A facility at the Bruce Nuclear Complex in Tiverton, Ontario, is used for the storage of ILW. The storage units are either in-ground concrete tiled trenches or above-ground concrete quadricell units. The Canadian government is currently dealing with the political and financial issues of implementing the Intrusion Resistant Underground Structures (IRUS) system. The system will store LLW in resistant concrete vaults for 500 years, a period of time for the level of radioactivity to decrease to exempt levels.

Site investigations are underway in China to locate and build 10 waste storage and disposal facilities in the Sichuan, Gansu and Zhejiang Provinces. Other storage locations for LLW and ILW will be identified on an as needed basis. The current concept, includes disposal in near surface facilities and rock cavities.

In accordance with the Czechoslovakian Atomic Energy Commission Waste Management Act, all radioactive waste from nuclear power plants is converted to a solid form prior to disposal at one of the two regional near surface disposal sites located at Dukovany and Mochovce. Short lived wastes that are low active and low leachable are disposed of in landfills after a store decay period.

In Germany, notification of intent to develop the Konrad iron mine as a site for a negligible heat-generating waste repository has been filed; site studies are continuing. The repository construction is underway, and operations are expected to follow in 1994 or 1995, assuming the license is granted. The facility capacity is expected to be about 650,000 cubic meters. The Asse salt mine was used for the disposal of more than 42,000 cubic meters of LLW between 1967 - 1976. Prior to unification, the Morsleben disposal facility, located in Eastern Germany, was used for the disposal of LLW.

A shallow land disposal site for industrial and institutional LLW has been in operation in Hungary for about 12 years. A disposal site for waste from nuclear power plant operations is currently in its licensing phase. The site is located in clay in the southwestern part of Hungary. Operation should be initiated following license approval.

India's strategy is to dispose of short lived LLW/ILW in shallow engineered structures and long lived ILW in geologic formations. LLW disposal facilities for NPP wastes are located at the nuclear power stations near Tarapur, Rajasthan and Madras, at BARC and at the reprocessing plant at Kalpakkam.

Korea's strategy to dispose of LLW includes: shallow land disposal, engineered trench burial, and a mined-out cavity in granite. To date, from the analysis performed, the underground "engineered cave" concept with engineered barriers is preferred. Of the 25 sites that were considered, three were selected for further evaluation. Under the current concept, the disposal facility will have an initial capacity of 500,000 drums and will have a final placed volume estimated to be at least one million units. Public opposition to the selection of a potential disposal site on an uninhabited island has delayed siting activities for the time being.

The storage facility for LLW in the Netherlands, which was built near the village of Borssele, initiated operations in 1992. This is also the location of the 450 MWe PWR-1 reactor. The municipality was one of two in the country that agreed to store nuclear waste in its territory. LLW/ILW will be stored for at least 50 years prior to disposal.

The Swedish Final Repository (SFR) for LLW and ILW at Forsmark began operating in 1988, and is considered by some to be one of the industry's most successful operating facilities. The SFR is situated in a rock cavern excavated in crystalline rock about 60 meters beneath the Baltic Sea (seabed), with access to the underground disposal area through 2-1000 meter long tunnels. The underground disposal facility is located near the Forsmark Nuclear Power Plant. The current capacity of the SFR is 90,000 cubic meters. However, additional capacity can be added to accommodate waste generated from decommissioning which is estimated to be 100,000 cubic meters of LLW.

In 1988, the National Cooperative for the Disposal of Radioactive Waste (NAGRA) in Switzerland, received approval for Project Gewähr from the Government. The approval authorized NAGRA to select and construct a facility for LLW/ILW. The current design concept envisions a disposal facility inside a mountain with horizontal access. The disposal area will be several hundred meters below the surface of the mountain, its design capacity is expected to be about 100,000 cubic meters of waste, which corresponds to 40 years of operation, and successive, independent multiple barriers will be used for long term protection and isolation of the radioactive waste from man's environment.

A LLW/ILW disposal site has been in operation for over 30 years at Radon, which is near Zagorsk, Russia, about 30 kilometers northeast of Moscow. About 5000 cubic meters of waste is received at Radon for disposal each year.

In South Africa, solidified and packaged LLW is emplaced in five meters deep shallow land trenches at Pelindaba. Sludges and solid wastes are buried in 200 liter drums or boxes. Liquid LLW is solidified with vermiculite/cement and packaged in metal drums prior to disposal. Four experimental trenches have been evaluated at Vaalputs to obtain data for selecting excavation techniques, backfilling methods, trench cap design and approaches to site restoration.

Since 1959, the U.K. has disposed of more than 700,000 cubic meters of LLW in eight trenches at the Drigg disposal site near the Sellafield Nuclear Complex. Seven of the eight trenches were direct land disposal units. The eighth is an engineered concrete barrier unit constructed with three separate bunkers with an overall size of about 270 meters long, 75 meters wide and 8 meters deep. The facility is expected to operate beyond the year 2020. The Drigg disposal site occupies about 107 hectares of which about 40 hectares are used for waste disposal.

The radioactive waste management company Nirex is investigating a site, also near Sellafield in Cumbria, as a potential geologic repository for long lived LLW/ILW. Test drilling at the Sellafield site has been under way for several years. So far, current studies indicate that the site is suitable for further investigations and characterization.

The U.S. Low Level Waste Policy Act (LLWPA) of 1980, as amended in 1985, requires that each state by January 1993, either individually or in compact agreements with other state(s), should develop a plan to site a LLW disposal facility and initiate operations of the facility by January 1996. In June 1992, the U.S. Supreme Court ruled that the LLWPA of 1980 was not binding. As a result, LLW disposal site investigations are not necessary, and individual states were free to develop their own programs and determine methods for disposing of the waste. There are three commercial LLW disposal sites in operation in the U.S. They are located in Beatty, Nevada; Hanford, Washington, and Barnwell, South Carolina. However, due to the political and institutional concerns raised within each of these states, waste receipts from other states may be restricted or stopped.

DISPOSAL STRATEGIES FOR HLW AND SPENT FUEL

Radioactive waste disposal systems should be designed to isolate the waste from humans and the environment for the necessary time periods and to ensure that potential releases of radioactive substances would not constitute an unacceptable risk. Such systems have been built for low level and short lived wastes. The same concept of safe isolation is incorporated in the design of repositories for high level and other long lived wastes. Although no HLW repository has been built to date, disposal of HLW in deep geologic formation has received strong support from the scientific and technical communities for many years. In 1957, the U.S. National Academy of Sciences issued a report which stated that HLW should be disposed of in deep geologic formations. This view was reaffirmed by experts of the CEC, IAEA and NEA in March 1991 when the experts issued "An International Collective Opinion on the Disposal of Radioactive Waste: Can Long-Term Safety be Evaluated?" The Opinion, in brief, states that the methods, techniques and analytical tools exists and are in place to determine the long term safety of HLW disposal in geologic repositories.

Research and Development Activities

In conjunction with the Commission of the European Communities (CEC), the Hades underground research laboratory (URL) near Mol, Belgium, was constructed in clay in 1984. Since then, the Nuclear Research Centre (CEN/SCK) has conducted various tests and investigations to develop a technology for disposal of ILW, HLW and alpha contaminated waste. One of the main objectives of the research centre is to evaluate the geology for long term disposal of HLW in clay. Galleries (drifts) have been excavated at a depth of 225 meters. Various tests are under way and some have been completed including thermomechanical heating, demonstration of excavation techniques and waste handling methods.

Investigations are under way on the island of Aspö, with the drilling and mining of a shaft for access to the Swedish hard rock URL in granite, as a possible geologic HLW repository. Construction of the URL is expected to be completed in 1994.

The Waste isolation Pilot Plant (WIPP) in Carlsbad, New Mexico, has suffered a series of setbacks: awaiting the official transfer of land from the Bureau of Land Management to the U.S. Department of Energy (USDOE), certification of the TRU-PACT canister, and receipt of a hazardous waste permit from the Environmental Protection Agency. All contributing to the delay of its experimental schedule for a number of years. A revised plan called for waste acceptance in October 1988, however, waste delivery is not expected until at least 1994-95.

Status of HLW Disposal Programs

To date, most countries with nuclear power are developing and implementing programs that will safely and effectively manage HLW and/or spent fuel.

China's national program has four discrete phases: 1.) technical preparations for site screening, 2.) geologic research and site characterization, 3.) in-situ testing and URL experiments, and 4.) repository construction. China is currently in the first phase. The HLW strategy calls for on-site storage of spent fuel for about ten years prior to reprocessing in the Quinhai province in northwestern China. HLW and alpha contaminated waste will be disposed of in a deep geologic repository. Two possible disposal sites have been identified for further studies. Performance assessment studies of final waste forms are under way as well as studies on radionuclide migration.

In accordance with a HLW management bill passed by the French Senate and the National Assembly in 1991, ANDRA is continuing detailed geographical investigations at four candidate sites (granite, clay, salt and schist). Upon completion of the site surface work, one or more sites will be selected for construction of an underground research laboratory. Studies and investigations will aim at characterizing the local geology, radionuclide migration and developing waste emplacement and backfilling techniques, to determine if the site(s) is suitable. Construction of a repository for ILW is expected to begin in 1995 with operations around the year 2000. If studies confirm the site's suitability, emplacement of HLW could start around 2010 .

Out of 100 sites screened, Finland has recently narrowed the number to three sites, at Olkiluoto, for further investigations to assess their suitability as a final repository for spent fuel. The three sites were judged to be most acceptable for continued evaluations based on the results of preliminary studies carried out since 1987. According to the schedule set by the government in 1983, the site for the repository is scheduled to be selected by the year 2000. A shaft to investigate the geology will be constructed around the year 2010. Repository construction is expected in the decade following 2010.

Germany's construction of the Ahaus interim storage facility for HLW was completed in 1991. In June 1992, the facility received its first shipment of fuel from the shut down THTR-300 high-temperature gas reactor. In the disposal program, a final evaluation to examine the legal, technical and organizational impacts of the May 1987 mining accident was completed. Construction of shaft one at the Gorleben site resumed in March 1989. Current plans call for completing site investigations and a final decision on the suitability of the site around the year 2000. The repository is expected to be operational after 2008.

In India, high level liquid wastes are stored in high-integrity stainless steel tanks in underground vaults for 3 to 5 years. Vitrified HLW is placed in interim engineered storage facilities for 20 to 25 years. India's strategy is to emplace vitrified HLW and solidified alpha-contaminated wastes in a deep geologic repository 25 years after reactor discharge.

A geological survey has been conducted at Horonobe in Hokkaido, on the northern tip of Japan. However, because of public opposition to siting a potential HLW repository in the area, interim storage (dry storage cask units) may be used. Japan is also continuing investigations into the feasibility of sub-seabed disposal.

Geological disposal of radioactive wastes in the Netherlands may be in a salt rock formation. The Netherlands and the Energy Research Foundation (ECN) are conducting preliminary studies directed at evaluating potential suitable sites and various repository concepts. However, there are no firm plans at the present to dispose of the wastes in a geologic repository. A national waste storage facility at Borssele became operational in 1992. The facility has a capacity of 110,000 cubic meters for LLW and ILW, and 24,000 cubic meters for vitrified HLW and 5000 tons of spent fuel.

Spain's current HLW strategy includes: increasing spent fuel storage capacity until a disposal facility is available; selecting a site for disposal in a geologic formation (clay, salt or granite); and developing an URL pilot facility (IPES) in granite in collaboration with the CEC.

In Sweden current plans call for the disposal of spent fuel in multiple encapsulated copper-clad waste packages. Some of the spent fuel will be reprocessed (abroad), which will result in a small amount of vitrified HLW. Field work, drilling and mining of an access shaft is under way for an URL at Aspö 20 km north of Oskarshamn. The planned studies will determine the suitability of the granitic formation. Site studies will be continued through 1993 with site selection some time around 2000. About 15 years of studies and tests will be performed at the URL before a final decision regarding its suitability is made.

In Switzerland, NAGRA was given permission to conduct additional test drilling to examine the underground crystalline geology at Siblinger in the northern part of the country. Test drilling was initiated in late 1988 which will supplement examination of the site's granite and sedimentary rock formations. NAGRA is now proceeding with a site selection program which involves four candidate sites. A site in crystalline rock in northern Switzerland is being considered in addition to sites in the central part of the country. Also, investigations in the Jura Mountains area are also being conducted. Selection of the most suitable site is expected some time around 2000. NAGRA has indicated that there is no time pressure on ILW and HLW, as these wastes will not require disposal before the year 2020. Currently, NAGRA's highest priority is the disposal of LLW and short lived ILW.

The Swiss utility NOK has applied for federal permission to build an intermediate waste storage facility at the Beznau site, that would accommodate LLW and ILW from the Beznau units, and HLW from reprocessing Swiss spent fuel abroad.

In Russia, spent fuel is to be returned by some foreign customers after a 5-10 year cooling period. Due to experience obtained in reprocessing VVER 440 fuel, a large scale plant for VVER 1000 fuel is being built. Industrial scale reprocessing plants with annual capacities of about 1500 tons uranium will be built on an as needed basis. The resulting HLW will then be immobilized in a glass matrix and stored until a disposal facility is available.

In the United Kingdom, at the present time there are no plans for HLW disposal. Vitrified HLW will be stored for 50 or more years.

In the U.S., in 1987, the Nuclear Waste Policy Amendments Act (NWPAA) designated the Yucca Mountain site in Nevada as the sole candidate site for detailed characterization. Exploratory shaft drilling, which initiates detailed site characterization, is expected to begin in 1994, provided the necessary permits for shaft construction can be obtained.

SUMMARY

The disposal of low and intermediate level waste has been practiced in a number of countries for over 35 years. At present, countries are continuing to rely on a mix of near surface and subsurface disposal facilities for disposal of LLW/ILW, but increasing their reliance on the use of engineered barriers to isolate the radioactive materials. Some countries such as Finland and Sweden have constructed disposal facilities at greater depths, and a number of other Member States are leaning towards deep geologic disposal for all radioactive wastes. Even though there are no deep geologic disposal facilities on-line for disposal of HLW, most Member States with nuclear power programs are evaluating potential repository sites for HLW. In continuing the development of radioactive waste disposal facilities, the IAEA, in response to requests by Member States, is developing standards, guides, practices, etc, which should lead to the harmonization of approaches to radioactive waste management at the international level. In addition, safe and effective waste management practices can be implemented by means of open co-ordinated national programs, and exchange of ideas and experiences with the technical community, politicians, media and the public, leading to closer collaboration and cooperation with these groups at all levels.

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